

Conformal Ablative Thermal Protection System for Planetary and Human Exploration Missions

R. Beck¹, J. Arnold¹, M. Gasch¹, M. Stackpoole¹, P. Wercinski¹, E. Venkatapathy¹, W. Fan², Jeremy Thornton² and C. Szalai³

¹NASA Ames Research Center, ²ERC Corporation, ³Jet Propulsion Laboratory

CONTEXT & OBJECTIVE

NASA OCT Game Changing Development Program What is our Mission?

To focus on transformative space technologies that will lead to advances in space and terrestrial capabilities, serve as a stimulus to the US economy while providing inspiration and opportunity to our nation's youth

Goals

- Develop Game Changing technologies that produce dramatic impacts for NASA's Space Exploration and Science Missions
- Capitalize on opportunities to leverage funding and cost-share from external organizations in technology areas mutually benefiting NASA and the other organizations
- Formulate and implement technology projects that deliver the required performance to stakeholders on schedule and within cost
- Deliver technology knowledge that is used internally for NASA missions as well as externally throughout the aerospace community

Vision

- Recent focus of the TPS community has been on ablatives
- Lessons learned:
 - Only 2 rigid TPS alternatives (PICA and AVCOAT) have been maturing each having significant integration issues
 - Low strain-to-failure makes direct bonding problematic
 - Existing systems are expensive and time consuming to install
 - Work was initiated under ETDD and ARMD to develop improved TPS

The Vision is to develop and deliver a high strain-to-failure conformal TPS to TRL 5 capable of reducing the cost and complexity of protecting an flight aeroshell

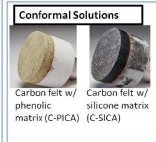
Why Conformal?

SOA

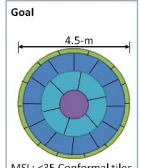
- Limited number of certified TPS
- PICA tile on a rigid heatshield is limited by small size billet manufacturing and low strain-to-failure resulting in high tile count and gaps with filler design
- Honeycombed concepts (AVCOAT) require extensive touch-labor, large curing ovens, and complicated NDE



MSL: 113 PICA Tiles



Dragon



Goal

MSL: <35 Conformal tiles (notional for ~1m² part)

Benefits

- Larger TPS part size reduces overall part count and would reduce assembly and integration costs
- High strain to failure TPS allows broader structural design options for rigid aeroshell structure

Systems Engineering Approach to Material Development

Mission Application Assessment

- MSL-like entry
 - 4.5 m diameter, composite heatshield structure
 - Peak heat rate=226 W/cm², peak shear=490 Pa, peak pressure=0.33 atm (+3-sigma design values)
- COTS LEO entry
 - Generic Environments include 25% margin
 - Highest heat load for a capsule shallow trajectory (28,400 J/cm²)
 - Heat rates for capsule and lifting ~150 W/cm², Max shear ~325 Pa (lifting), Max pressure ~0.25 atm (lifting)

Material Performance Goals

- Demonstrate performance capability of conformal ablator under relevant aerothermal heating conditions
 - Goal to survive MSL-like heating, pressure, and shear environments
 - Goal to survive COTS-like heating loads

Key Performance Parameters

Conformal Ablators Key Performance Parameters	Category Definition	State-of-the-Art Value	Justification
KPP-C1	Survivable for MSL-like and COTS aerothermal environments Capability required for future Mars and COTS missions	PICA: >250 W/cm ² , 0.33 atm, 490 Pa shear	Current goal for Conformal Ablator is to meet MSL-like conditions while satisfying COTS heat shield conditions
KPP-C2	Strain to Failure > 2%	PICA (<1%) Avcoat (~1%)	High strain to failure and use of felts for substrates enables factor of 3.0 reduction in heat shield parts count
KPP-C3	Manufacturing Scalability Assesses the likelihood that the technology concept will successfully scale to the large sizes required by mission architectures	20" x 40" PICA max tile size (1m cast monolithic)	Eventual application will require large panels, seams, and closures. Heat loads define ablator thickness. The MDU, arcjet testing, and analysis will prove scalability of the ablator to full-scale.
KPP-C4	Response Model Fidelity Ability to reliably and repeatedly predict the thermal response of the material to the applied environments	Mean: bias error 30%, Time to peak error 30%, Recession 150%	Working from low to mid to high fidelity models - need the ability to estimate thicknesses for target mission design

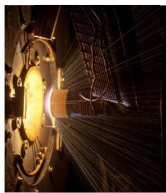
CA250 Project Schedule

	FY2012 1 st Half	FY2012 2 nd Half	FY2013 1 st Half	FY2013 2 nd Half
Key Decision Gates	Downselect Conformal Ablator	Establish Industry Partnerships	MDU manufacturing readiness review	Conformal Ablator at TRL 5
Systems Engineering	System Requirements	System Architecture	System Integration	System Verification
Develop Industry Partnerships and Scale Up	Identify potential partners	Conduct initial discussions	Finalize partnerships	Scale up manufacturing
Develop/Deliver Conformal Ablator Material at TRL 5	Material development	Material development	Material development	Material development

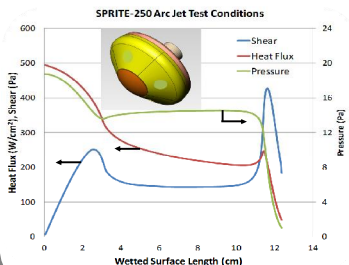
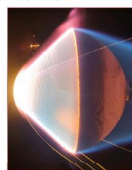
Perform Arc Jet Testing and Materials Properties Testing to Downselect Best Material

Arc Jet Testing Approach

- Test n material variations in stagnation conditions to determine best 2 materials

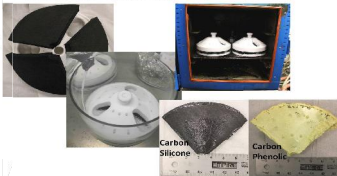


- Test 2 best materials in $r_b = 20$ cm, 55° sphere-cone configuration to achieve p, τ , and q conditions similar to MSL



Conformal Materials Manufacturing Approach

- Place in Mold - Infuse & Cure - Dry

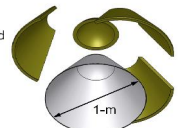


Establish Industry Partnerships for Scale-Up

- Industry Request For Information - Conformal TPS Manufacturing Scale-Up

Objective

- Manufacturing Plan for felt-based conformal ablator materials of at least 1-m diameter; which includes the necessary processes, procedures, equipment, and any services required
- Non-destructive methodologies necessary to examine variations in the felt structure and the resulting conformal ablator and for bond verification
- Proposed specifications for certified TPS processing and NDE evaluation of the ablative materials
- Design support and manufacture of a 1-meter class manufacturing demonstration unit (MDU)



- Vendor will be required to supply small-scale samples for testing followed by large-scale materials for application to the 1-m diameter MDU

- Current maximum available thicknesses of carbon felt is ~2-cm, the Project is working to develop thicker felt (6-7 cm) with industry partners
- Work-to-go planned to reach TRL5 in 2 years
 - Technology transfer for scale up, and evaluation of industry materials
 - Development of attachment and seam techniques
 - Perform further arc jet tests and thermal properties tests to provide data for development of a mid-fidelity material response model
 - Develop mid-fidelity material response model
 - Manufacture MDU
 - Develop NDE techniques to evaluate material and bond conformance
 - Develop material specifications
 - Begin technology push to new missions

CONCLUSION & OUTLOOK

Game Changing: we are looking to create a high strain-to-failure TPS with dramatic reduction in cost and complexity

Work-to-date shows promise that we can achieve our TRL 5 goal for conformal ablator with industry partnerships and focused testing